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VI-3. EVALUATION OF AQUABLOK™ ON CONTAMINATED SEDIMENTS TO REDUCE MORTALITY OF FORAGING WATERFOWL

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INTRODUCTION

The U.S. Army has used the Eagle River Flats (ERF) since 1945 as an impact area for artillery shells, mortar rounds, rockets, grenades, illumination flares, and other activities involving explosive ordinance. In August of 1981, hunters discovered large numbers of duck carcasses in ERF. Since then, the Army and other federal and state agencies have been involved in identifying the cause of waterfowl mortality. On 8 February 1990, the Army temporarily suspended firing into ERF due to the suspected correlation between the chemical components of explosives and duck deaths (Quirk 1991). In July 1990, a sediment sample collected from ERF was suspected of containing white phosphorus (WP). By February 1991, the Cold Regions Research and Environmental Laboratory (1991) concluded that WP in ERF was the cause of waterfowl mortality.

Waterfowl populations have been decreasing continent-wide (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1989). In 1994, many species showed increases in numbers (Harrison and Harrison 1994). However, in relation to the past 40 years the increase is not substantial (Harrison and Harrison

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1994). ERF is an important spring (April to May) and fall (August to October) waterfowl staging area, but WP represents a significant hazard to migrating waterfowl (CRREL 1991). This concern has stimulated efforts to develop an effective remediation action.

One product that we pilot-tested in 1993 was AquaBlok™ (formerly Bento-Balls™), a blend of calcium bentonite/organo clays, gravel, and polymers which bind together to form a sealant (NewWaste Concepts Inc., Perrysburg, OH). Preliminary data indicated that AquaBlok™ could prevent foraging mallards from encountering contaminated sediment by forming a physical barrier (Pochop et al. 1994). However, 907 kg of material was needed to cover a 7- × 7-m area about 8 cm thick and only a portion of the pond was covered.

The objectives of our definitive study were to evaluate the longevity of the AquaBlok™ and its effects on waterfowl foraging behavior and mortality on ERF. In addition, we looked at the logistics and costs of applying the quantity of AquaBlok™ necessary to treat an isolated pond up to 0.5 ha in size to determine the feasibility of using AquaBlok™ as an interim remediation action on ERF.

METHODS

Study site

Two sites on ERF were used for this study, one located in area C and the other on Racine island (Fig. VI-3-1). Area C includes a single large pond with a connected series of smaller ponds and inlets along the east edge of ERF (Racine and Walsh 1994). In the northwest portion of the large pond we built a control pen which measured approximately 3200 m^2 (Fig. VI-3-2). Racine island, which is formed by two channels of Eagle River, has a large pond formed by an old channel which is surrounded by bulrush marsh and a smaller pond to the north (Racine and Walsh 1994). The smaller pond, which has a large number of craters associated with it, was used as the treated pen. This pen was irregularly shaped but encompassed approximately 4500 m^2 during the pretreatment and 4000 m^2 during the posttreatment (Fig. VI-3-3). The size was reduced during the posttreatment because there was not enough AquaBlok™ to treat the farthest northwest pond. The pens were constructed of polypropylene netting (2 cm mesh) at a height of 2 m above the sediment.

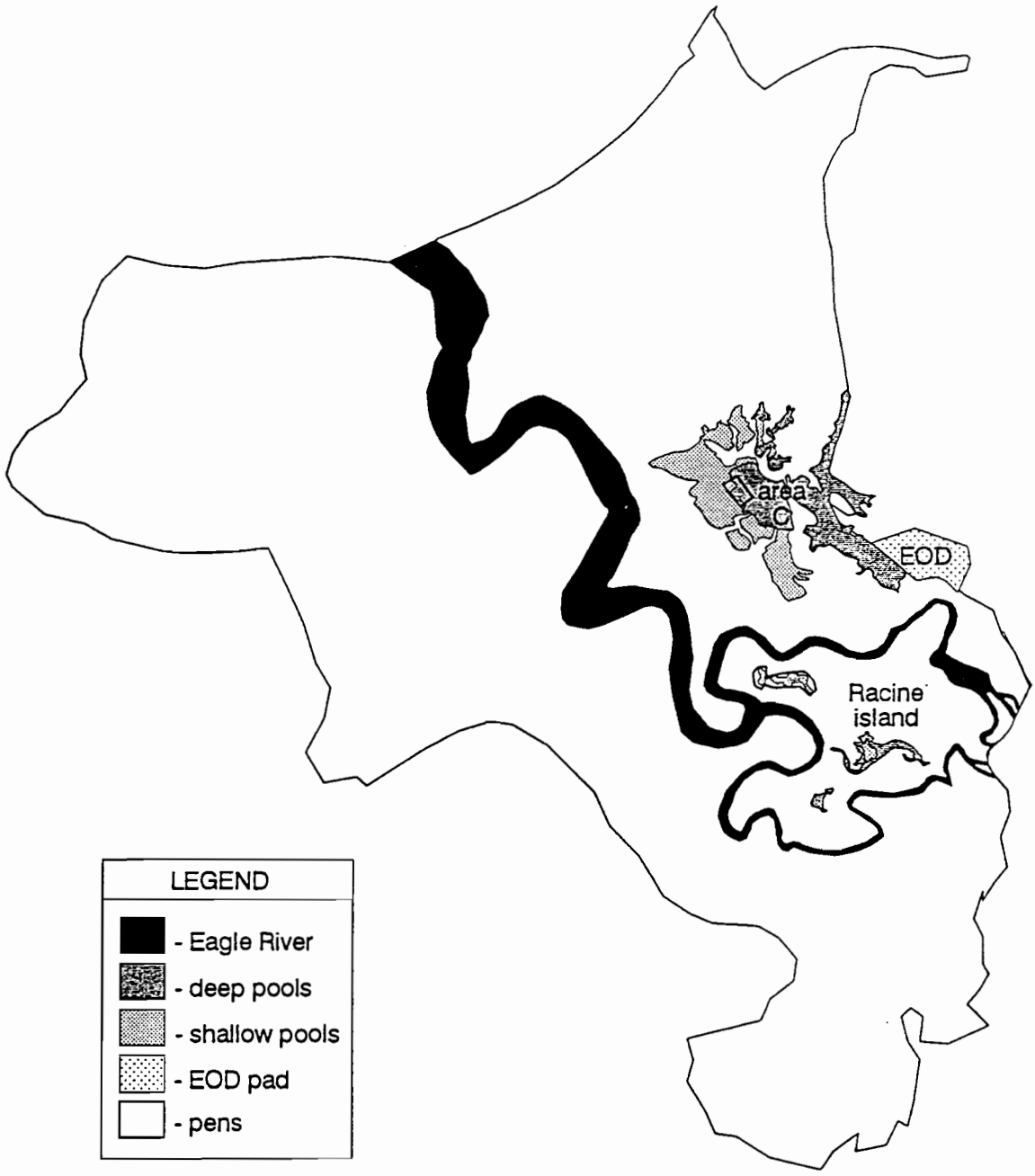


Figure VI-3-1. Eagle River Flats showing the locations of the pen in area C, the pen on Racine island, and the Explosive Ordinance Disposal (EOD) pad.

Pilot study

In 1993, we applied AquaBlok™ to a 7- × 7-m plot in area C (Fig. VI-3-2). One-day posttreatment, we measured the thickness of the 7- × 7- m plot at 10 evenly distributed locations across the material. In 1994, we repeated the measurements using an 8-cm-diameter plastic tube to obtain a core sample to determine if there

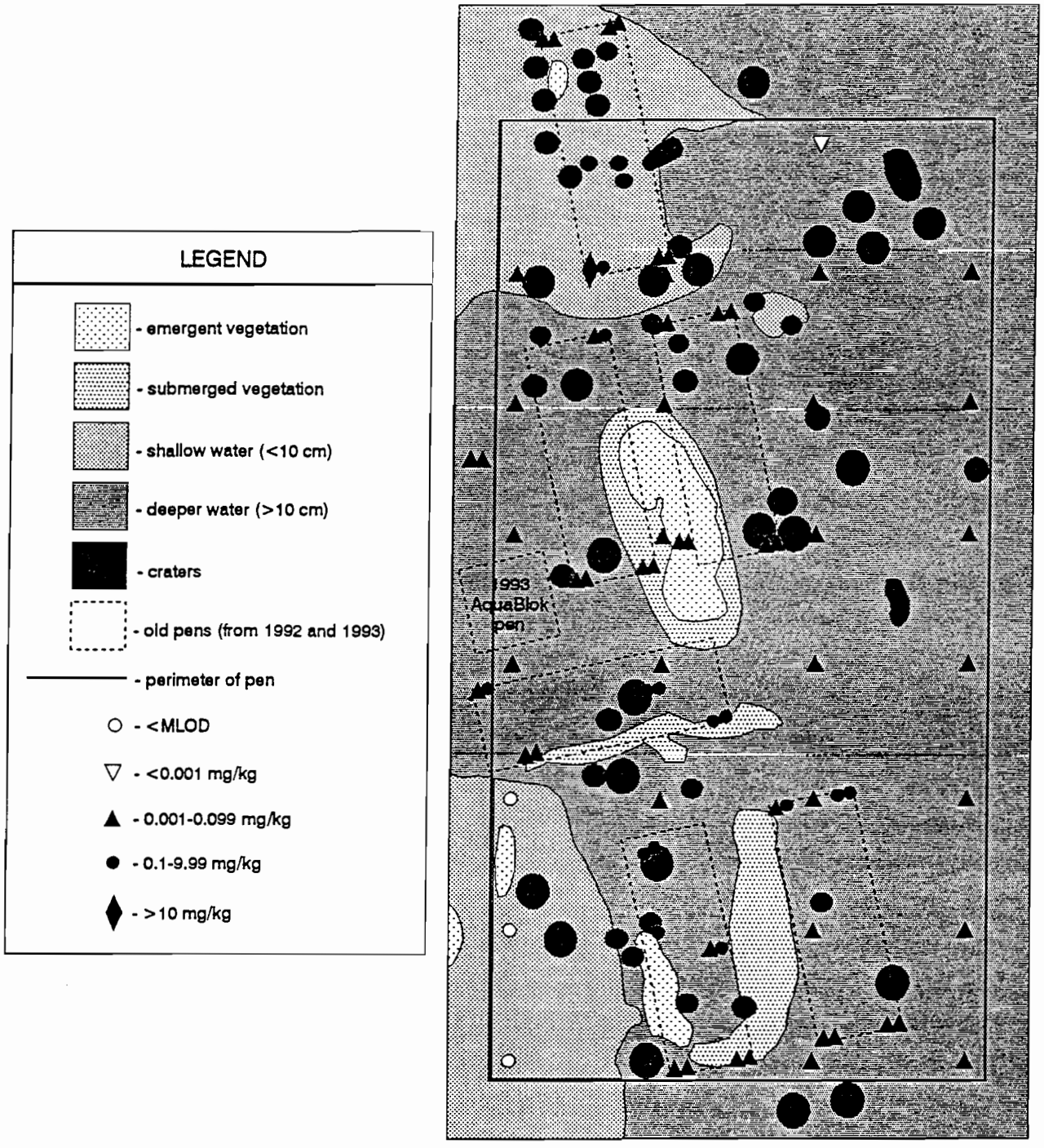


Figure VI-3-2. Diagram of the pool C (control) pen showing white phosphorus concentrations and distribution throughout the sediments, 26 May 1994, Eagle River Flats, Alaska.

were any changes in the thickness of the barrier. In addition, we measured the amounts of organic matter/sediment deposited at the same locations. We also noted the presence of vegetative growth on the barrier.

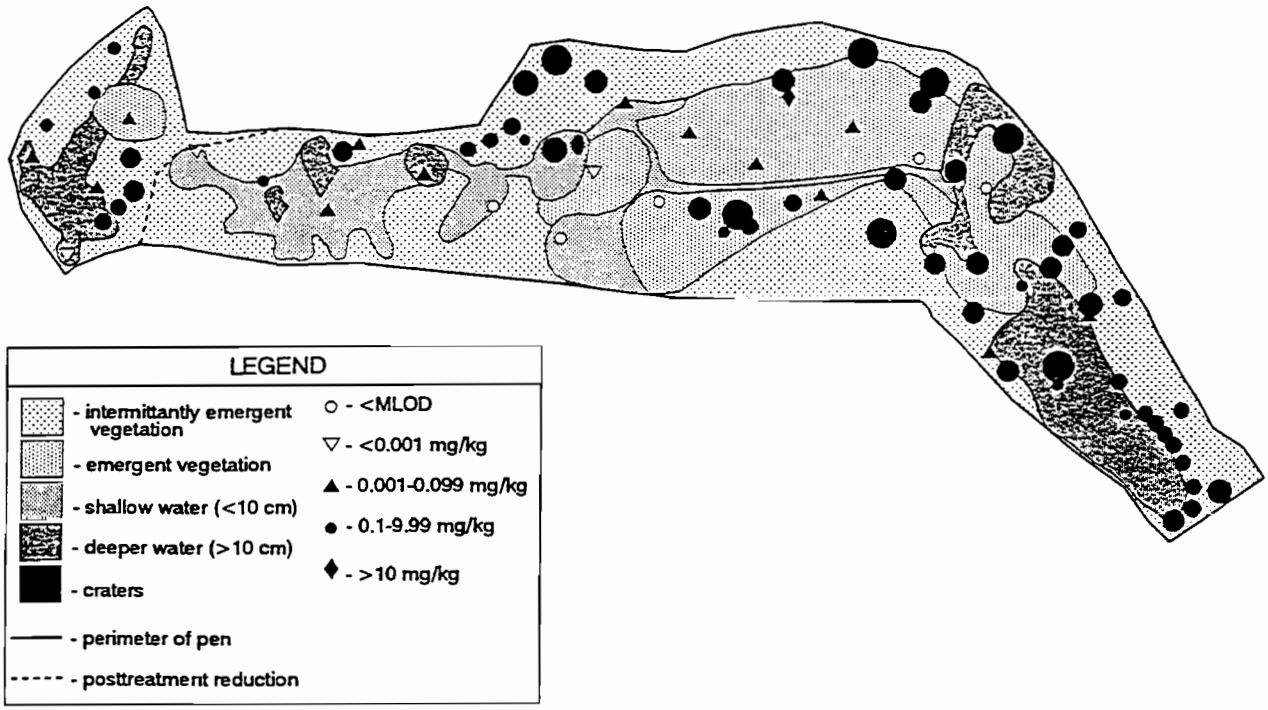


Figure VI-3-3. Diagram of the Racine island (treated) pen showing white phosphorus concentrations and distribution throughout the sediments, 21 June 1994, Eagle River Flats, Alaska.

Definitive study

Prior to study initiation we collected sediment samples from each pen (30 from control, 29 from treated area) for analysis of WP concentrations; samples were collected at 10-m intervals on a marked grid. Sediment (about 3 cm deep) was scooped from an area up to 30 cm^2 around the base of each stake to fill a 500-mL sample jar. The samples were shipped to a contract lab (Waterways Experiment Station, Vicksburg, MS) for gas chromatography analysis.

Water depths were taken daily before or after the morning observation during the posttreatment period. Four stakes with stream gauges attached were placed in the control pen at least 10 m from each corner. Six stakes with stream gauges were placed in the treated pen within 1 m of the fence, 2 in potholes and 4 distributed throughout the pool.

The AquaBlok^{TM} was produced on-site; ingredients were purchased locally and mixed using 8-m^3-concrete truck. After mixing the AquaBlok^{TM}, it was loaded into a standard dump truck and stored on the Explosive Ordinance Disposal (EOD) pad under a tarp until application (<5 days, Fig. VI-3-1). Eighteen batches of AquaBlok^{TM} were mixed in 5 days and weighed a total of 148,300 kg.

The drop bag used for applying the AquaBlok™ was a PVC bulk bag, model HD 32-36, Springfield Special Products, Springfield, MO. A fork lift was used to hold the bag while a front-end loader filled it with up to 2,500 kg of AquaBlok™. The bag was then rigged approximately 10 m below a Blackhawk helicopter for application. The AquaBlok™ was applied in a 1.8-m swath from a height of about 27 m at an airspeed of approximately 8 km/hr. Fifty-seven loads were applied during 9 hr over 2.5 days. About 141,200 kg of AquaBlok™ was applied to the Racine island pen and about 7,100 kg landed outside of the pen.

After treatment, the thickness of the AquaBlok™ was sampled. An 8-cm-diameter plastic tube was used to pull-up a plug that was measured in four locations using a caliper and the results averaged. The beginning and end portions of runs located outside of the pen were sampled as well as dry and wet areas including potholes and pools. A total of seven core samples were measured.

To determine waterfowl mortality, 24 wing-clipped mallards grouped in random assignments from sex-by-size classes (the heaviest 12 males and females in the first group, the next 12 heaviest in the second, etc.; then each group was randomly assigned to a treatment - pretreatment or posttreatment control or treated enclosure), were placed into each of the 2 enclosed ponds for 10 days to establish baseline mortality. After the AquaBlok™ was applied and allowed to settle for about 45 hr, another group of 24 wing-clipped mallards was placed into each enclosure. The ducks remained in the enclosures 20 days posttreatment.

Throughout testing, supplemental food was available *ad libitum* on floating platforms. Mallards were observed twice daily for 1 hr between 0700-1100 and 1600-2000 hr to determine foraging behavior. Because the 2 sites were separated by about 800 m and travel over the Flats had to be conducted using the "buddy" system, both sites could not be observed simultaneously. Therefore, one site was randomly picked to start observations then the other site was observed, usually within an hour after completion of the first site observation. Observations were alternated between sites daily (e.g. the first site observed one day became the second site observed the next day). At 1-min intervals, the observer recorded the numbers of mallards feeding or loafing. A mallard was considered feeding when it dipped its head below the surface and loafing when it was swimming, preening, or floating. Percent feeding activity was based on the number of feeding bouts recorded (morning plus evening observations) divided by the total number of feeding bouts possible from the remaining live ducks.

Mallards that died were collected and analyzed for WP residues. A total of 7 mallards, 1 from control and 2 from treated pens during the pretreatment period and 2 from control and 2 from treated pens during the posttreatment period, were analyzed.

RESULTS

Pilot study

The thickness of AquaBlok™ 1-day posttreatment in Pool C during 1993 was approximately 8 cm. In 1994, the thickness ranged from 2 to 9 cm with a mean of 6.2. In addition, the amount of organic matter/sediment deposited at the same locations ranged from 0.5 to 2.5 cm with a mean of 1.6. There was no vegetative growth observed on the barrier.

Definitive study

WP concentrations from sediment samples in the control pen ranged from less than the Method Limit of Detection (<MLOD) to 3.4 mg/kg with a mean of 0.2 and samples in the treated pen ranged from <MLOD to 19.0 mg/kg with a mean of 1.3. Samples from the control pen were similar to sediment samples analyzed for WP concentrations in 1992, 1993, and later in 1994 (Table VI-3-1).

Water depths in the control pen ranged from 10.2 to 13.9 cm in the east half of the pen and from 2.3 to 11.4 cm in the west half of the pen. Water depths in the treated pen ranged from 0 to 11.7 cm in the pool and from 5.1 to 50 cm in craters. Both pools were at maximum depths during the pretreatment because of a June flood and became shallower as the experiment progressed (Fig. VI-3-4). Neither pool flooded again until 7 September 1994.

The thickness of the AquaBlok™ ranged from 4.3 to 9.1 cm over level ground. Craters appeared to be unevenly covered with the thickness ranging from <11.9 to 25.4 cm. The initial impact created its own crater but then also had material deposited on top for a total thickness of 40.6 cm (Fig. VI-3-5).

During pretreatment, 23 mallards died in the control pen and 15 died in the treatment pen over 10 days. Posttreatment, 24 mallards died in the control pen. Only 3 mallards died in the treatment pen, the first on day 14, the second on day 15 and the third on day 16 (Fig. VI-3-6).

Table VI-3-1. Mean concentrations of white phosphorus in control (pool C) and treated (Racine pool) pools at ERF.

Pen	*Date*	*Concentration (mg/kg)*
	Pool C	
New	5-26-94	n* = 27/30 x = 0.1555 Range = 0.00038–3.4
Old	6-29-94	n** = 24 x = 2.5182 Range = 0.0021–58
Old	6-8-93	n** = 24 x = 0.3485 Range = 0.00337–5.25
	May 1992	n = 10 x = 0.0131 Range = 0.0017–0.0152
	8-20-92	n*= 30/31 x = 0.2728 Range = 0.00138–6.65
	Racine Pool	
New	6-21-94 (pretest)	n*† = 24/29 x = 1.3009 Range = 0.00017–18.95
New	6-21-94 (posttest)	n*† †† = 19/29 x = 1.6368 Range = 0.00019–18.95
(CRREL 1994)	6-8-93	n = 4 x = 0.11 Range = 0.001-0.41

*Samples below the method limit of detection (<MLOD) were not included in the mean. Number of samples used in determining the mean/total number of samples taken.
†The average of duplicate subsamples was used to calculate the mean.
**Samples were taken from the same sample sites.
††Five samples were not included in the mean because the size of the posttreatment pen was reduced.

There was more foraging activity in the treated than in the control pen during the pretreatment period. However, there was more foraging activity in the control pen during the posttreatment period. In addition, mallards were observed feeding on supplemental food more often in the treated than in the control pen during the posttreatment period (Fig. VI-3-7). However, the mallards in the treated pen were often observed dabbling on their way over to the supplemental food and on the way back to their loafing spot.

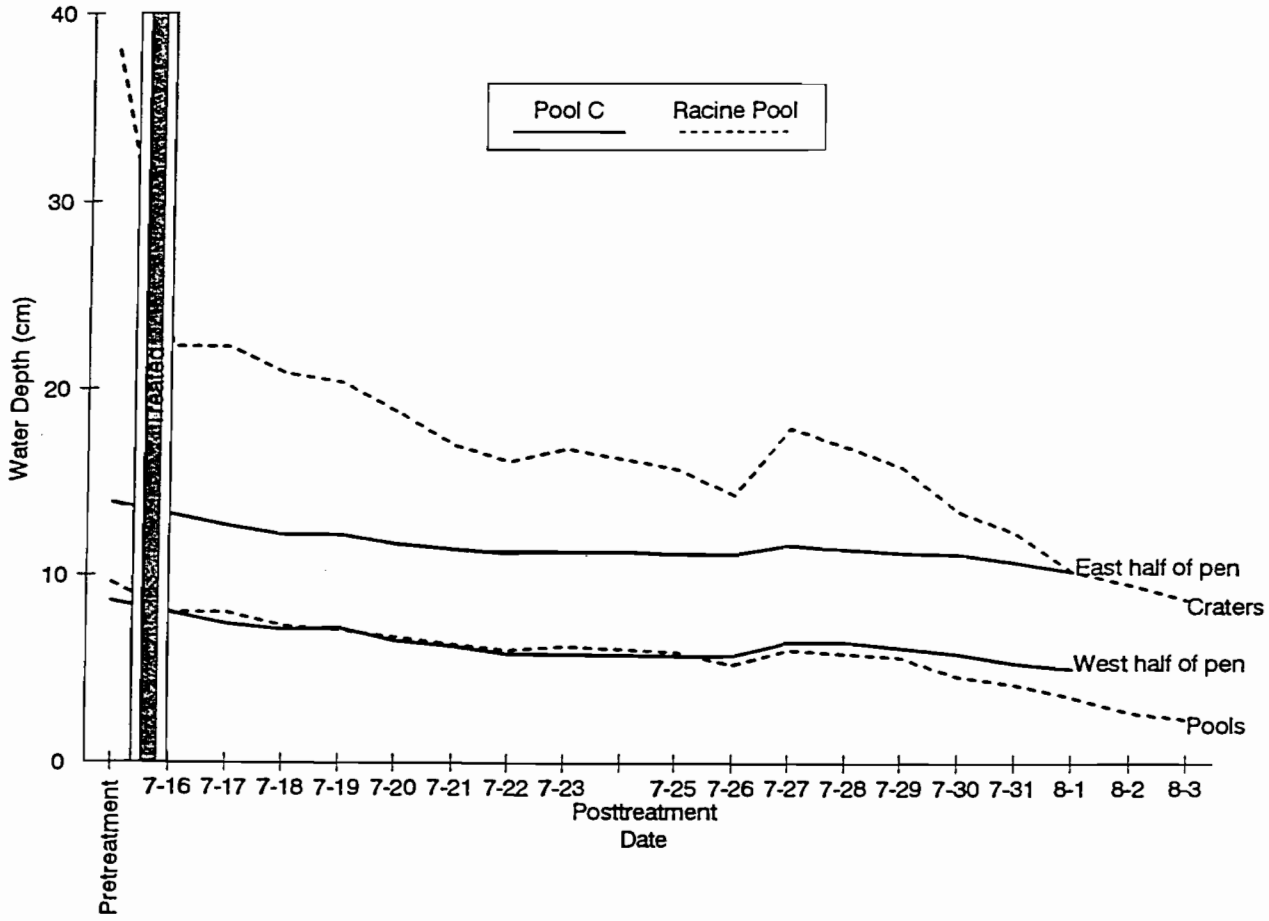


Figure VI-3-4. Water levels in control and treated pools, 1 July–3 August 1994.

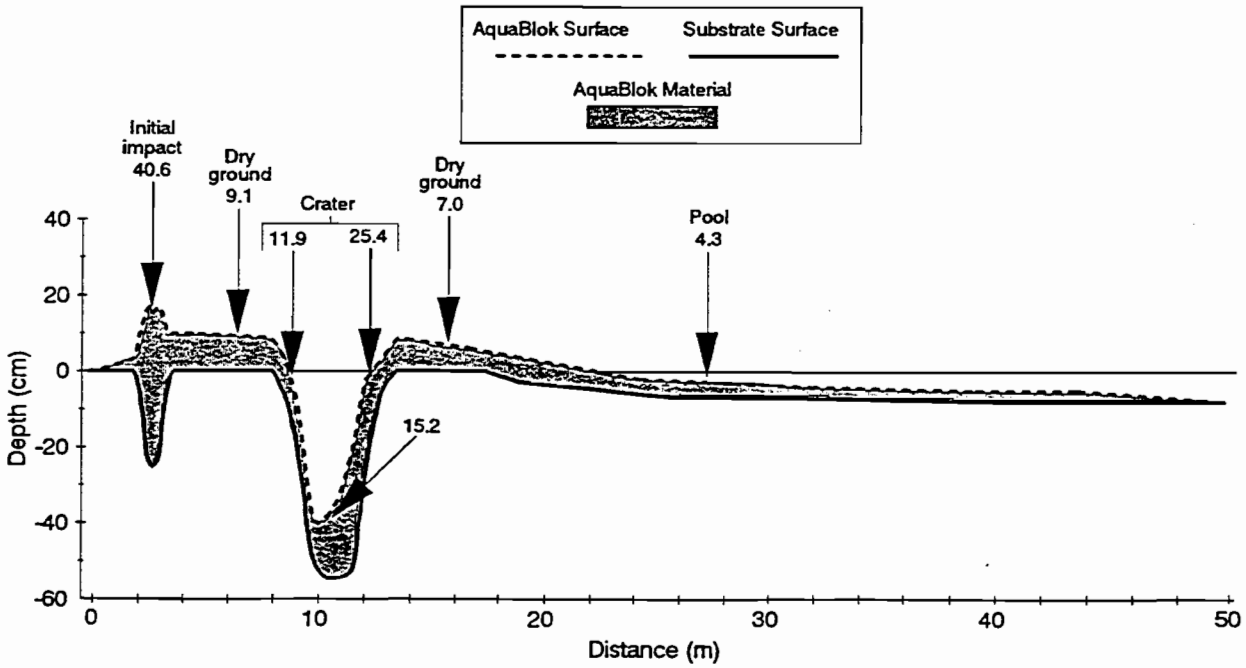


Figure VI-3-5. Average thickness of the AquaBlok™ from initial impact to end of run, 26 July 1994.

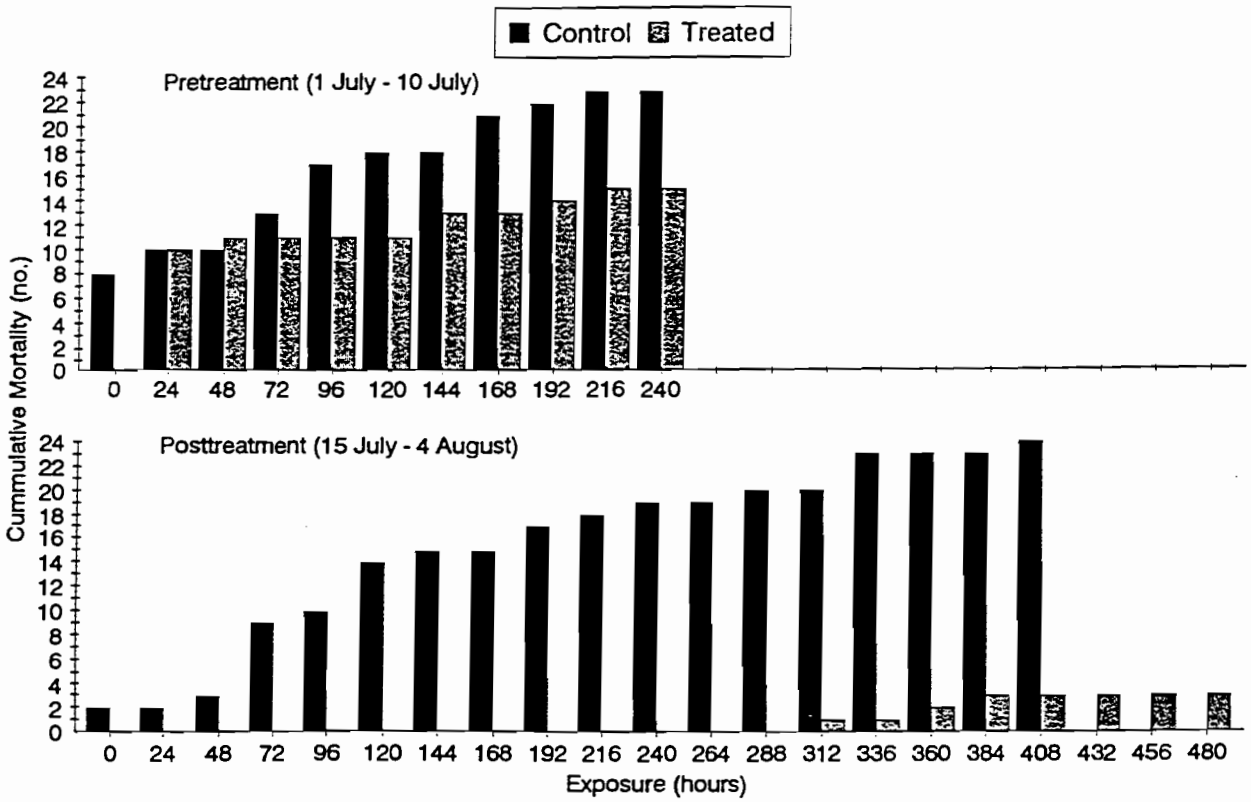
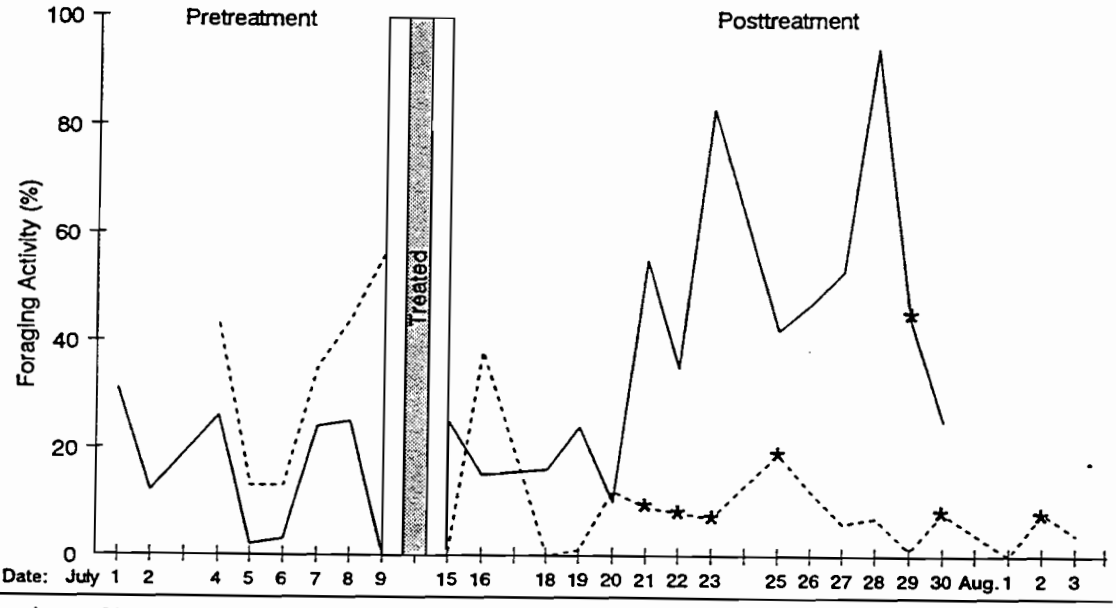


Figure VI-3-6. Mortality of mallards in control and treated pools, 1 July–4 Aug 1994.



		Date: July	1	2	4	5	6	7	8	9	15	16	18	19	20	21	22	23	25	26	27	28	29	30	Aug. 1	2	3
Feeding[1] Bouts (no.)	control	——	31	12	26	2	3	24	25	0	25	15	16	24	10	55	35	83	42	47	53	94	44	25			
	treated	----			43	13	13	35	44	56	0	38	0	1	12	9	8	7	19	12	6	7	1	8	0	8	4
Live[2] Mallards (no.)	control	——	24	14	14	8	7	6	4	3	22	22	17	14	11	10	9	7	5	5	4	4	2	1			
	treated	----			13	13	13	11	11	11	24	24	24	24	24	24	24	24	24	24	24	24	23	22	21	21	21

*Mallards were observed feeding on supplemental food.
[1] Morning and evening bouts were combined.
[2] Number of live mallards at the end of the evening observation.

Figure VI-3-7. Mallard foraging activity in control and treated pools.

Six out of the seven mallards analyzed for WP concentrations had detectable amounts in the digestive tract and/or fat (Table VI-3-2). The one mallard that did not have detectable levels of WP was sampled from only the gizzard and fat.

DISCUSSION

The concentrations and distribution of WP in the control and treated pools were similar to those in preceding years. It would be difficult to detect any reduction in WP concentrations in the sediment over just a few years because of the highly variable nature of WP distribution and because WP occurs in the sediment as particles of varied sizes (Racine and Walsh 1994). However, the outlier of 58 mg/kg found in the control pool in 1994 could be a result of removing old pens (pulling up 30 cm long landscaping pins with netting). Core samples show that WP can be detected to 50 cm in pool C (Racine and Walsh 1994). Conversly, it may simply be an indicator of the variability of WP contamination in ERF. For example, WP concentrations of interval samples from pool C were as high as 219 mg/kg (Racine and Walsh 1994).

Data on the thickness of the AquaBlok™ barrier applied to a 7- × 7-m area in pool C shows some reduction from 1993 to 1994. Some of this reduction may be attributed to horizontal movement associated with the removal of plastic panels placed during treatment. It is also possible that scouring or movement of ice contributes to the horizontal movement of the barrier. Because some areas in the Racine island pen were much thicker than others, some horizontal movement may prove to be beneficial in covering areas that were not treated thoroughly. The sedimentation and organic matter deposition measured in 1994 on the 7- × 7-m area treated in 1993, was expected. It should not inhibit the effectiveness of the AquaBlok™ in reducing the movement of WP particles below the barrier. Racine island is only intermittantly flooded, hence sedimentation will probably not occur as rapidly as in pool C.

The lack of vegetative growth on the 7- × 7-m barrier in pool C may be due to either scouring by ice breakup or to the character of the area. We expect that vegetation in the Racine island pen will recover. Lab tests show that certain plants will grow on the AquaBlok™ (C.H. Racine pers. comm. 1994).

Low water levels probably enhanced the likelihood of a mallard picking up WP in the treated pen. For instance, because of the higher feeding activity in the

Table VI-3-2. White phosphorus (WP) in captive-raised mallards (all were about 1 year old) during the AquaBlok™ test, 1 July–4 August 1994.

Date (hours of exposure)	*ID #*	*Sex*	*Weight change* (g)*	*Notes*	*WP detected (tissue amount)*
			Control - Pretreatment (initially exposed 7-1-94)		
7-6-94 (118)	154	F	–100	Affected/lethargic upon arrival at 0755 h, died at 0841 h (in water)	GZ: 38† DUO: <10 SIN: <10
			Treated - Pretreatment (initially exposed 7-1-94)		
7-7-94 (148)	223	M	–100	Dead upon arrival at 1630 h	EP: <50† GZ: 1100 DUO: <50 SIN: 400 LIN: 450 CEC: <50
7-9-94 (197)	191	F	–150	Convulsing upon arrival at 1645 h (not in water), euthanized about 15 min later	EP: <10† ** GZ: <10 SIN: <10
			Control - Posttreatment (initially exposed 7-15-94)		
7-20-94 (121)	237	F	–150	Started convulsing at 1006 h, died at 1011 h (in water)	EP: <10† GZ: <10 DUO: <10 SIN: 25 LIN: 78 CEC: <10
7-29-94 (345)	179	M	–150	Affected/legarthic upon arrival at 1825 (attempted escape when approached), had a few minor convulsions and died within 10 min (not in water)	EP: <25† GZ: 1050 DUO: <25 SIN: 25 LIN: <25
			Treated - Posttreatment (initially exposed 7-15-94)		
7-29-94 (335)	?	F	?	Went into convulsions at 0800 h, died at 0815 h (in water). Unable to retrieve body before scavenged	?
7-30-94 (360)	185	M	0	Arrived at 0930 h, dead upon arrival (in water)	Fat: 0.069†† GZ: 0.088
7-31-94 (384)	242	M	–200	Affected (7-30?) upon upon arrival at 0900 h, had difficulty breathing, had 2-3 mild convulsions and died at 0915 h (not in water)	Fat: <MLOD†† GZ: <MLOD

*Weight immediately prior to shipping to Alaska minus weight after death. Mean weight loss for all ducks that died and were not scavenged: pretreatment, control -163 and treated -163; and posttreatment, control -150 (2 ducks gained weight) and treated -100.

†Ducks were sampled throughout the entire digestive tract (esophagus [EP], gizzard [GZ], duodenum [DUO], small intestine [SIN], large intestine [LIN], cecum [CEC]).

**The WP concentration was near the Method Limit of Detection (MLOD; 0.01 mg WP per kg tissue).

††Only the fat and gizzard (GZ) was sampled for WP.

treated versus the control pen during the pretreatment period, we should have seen at least equal mortality between treatments. However, because water levels were deepest during the pretreatment, the ducks in the treated pool had more areas in which to feed than during posttreatment. The shallow areas in the treated pen intermittantly dry out, which under the appropriate sediment moisture and temperature conditions, would allow for some sublimation of WP (Walsh et al. 1994). In contrast, deeper areas which may be too deep to feed in during high water levels, rarely dry out so that little sublimation of WP could occur. Therefore, the treated mallards could forage with less risk as long as the deeper water levels were maintained. But, as soon as the water levels dropped, as in the posttreatment period, the risk increased because the ducks were being forced into fewer areas of possibly greater concentrations of WP. This may have contributed to the 3 deaths during posttreatment. Evidence from water levels indicates that the deepest areas in the treated pen would be in craters which were probably unevenly covered by AquaBlok™. The variablility of WP concentrations due to drying, might also have occurred in the control pool had it not been for the deeper water levels and continuous nature of the pool (no large areas were completely dry). In fact, portions of the control pool did dry out during August. However, this was after the test was completed and this season was abnormally dry for Eagle River Flats (B. Gossweiler pers. comm. 1994).

Overall, we felt that this large-scale field test was a rigorous test of the efficacy of the AquaBlok™ in reducing waterfowl mortality for several reasons. First, although the coverage we obtained was not even in craters, the coverage we were able produce was what could be reasonably be expected in a large scale field operation. The uneven coverage in craters and the single crater that looked like it was missed, could have been taken care of by either applying the AquaBlok™ from the helicopter in more than one direction or by broadcasting the AquaBlok™ with another method such as a pneumatic pumping system. Dealing with the problem of covering craters on ERF is important because areas of high crater density are associated with sediments contaminated with WP (Racine and Walsh 1994).

Second, the areas used in this test were among some of the areas of greatest WP contamination on Eagle River Flats. This allowed us to test the AquaBlok™ under the worst case scenario rather than testing the barrier in less contaminated areas which would not give us a strong test of its effectiveness. Third, our mallards could not freely leave the test pens in contrast to wild ducks. Our ducks did

have supplemental food during the entire study, but this presence did not deter ducks from dabbling in the sediment. Evidence of WP concentrations in mallards from both the control and treated pens support this. Further, though there was probably little available food in the sediment of the treated pen, mallards may have been trying to pick-up grit as well as sampling for food. Finally, the water levels at the end of the test period were low enough to force ducks into foraging in what should be the areas of greatest WP concentration, since these areas are less likely to dry enough to allow WP to sublime. For these reasons, we feel that the data collected to date indicate that the AquaBlok™ shows promise for reducing mortality of waterfowl from WP on ERF.

The cost of materials ($0.15/kg) and manufacturing ($0.02/kg) to apply the AquaBlok™ to the 0.5 ha used in this study was about $26,000. This cost does not include labor or application. No costs are currently available for using a pneumatic pumping system on Eagle River Flats, Alaska. A feasibility test on the existing pumping system or installing a separate pumping system would help determine the effectiveness of a pumping system in applying AquaBlok™ to an area of Eagle River Flats, including coverage and cost issues. Further, fine tuning the application rate of the AquaBlok™ using either application method can probably provide a more cost effective approach than was realized in this study.

RECOMMENDATIONS

A follow-up test of the AquaBlok™ placed in the Racine island pen after the winter and spring thaw will help us to determine how long it will remain effective in the field. If the longevity of the barrier were sufficient to be given serious consideration for covering ERF, investigations of application methods that would adequately cover uneven terrain such as highly cratered areas would need to be considered as well as the optimal application rate for cost effectiveness.

SUMMARY

The results of a 1993 pilot study indicated that the AquaBlok™ barrier system could reduce mortality of foraging waterfowl on Eagle River Flats, Alaska. Therefore, a definitive study was conducted in 1994. Our objectives were to evaluate

the longevity of AquaBlok™ when applied to an isolated pond up to 0.5 ha in size and to measure its effects on waterfowl foraging behavior and mortality on Eagle River Flats. During pretreatment, 23 mallards (*Anas platyrhyncos*) died in the control pen and 15 died in the treated pen over 10 days; during posttreatment, 24 mallards died in the control pen and 3 mallards died in the treated pen. During pretreatment, the mallards in the treated pen were observed feeding more than those in the control pen. However, control ducks were observed feeding more frequently posttreatment. Data collected to date indicates that AquaBlok™ shows promise for reducing waterfowl mortality from white phosphorus poisoning on Eagle River Flats, Alaska.

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